T-2-5-1

R&D for Neutron Cross-Section Measurements at RIA

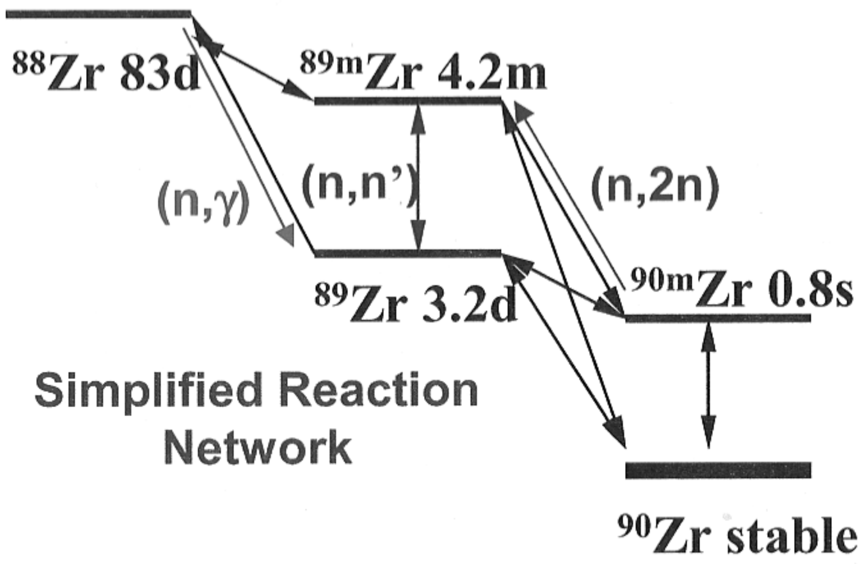
Larry Ahle, Brian Rusnak, and Mark Stoyer
Lawrence Livermore National Laboratory

RIA R&D Workshop
Bethesda, MD
August 27, 2003

This work has been performed under the auspices of the US DOE by UC-LLNL under contract W-7504-ENG-48.

Stewardship And Astrophysics

Both stockpile stewardship and astrophysics need better neutron cross-section evaluations on unstable isotopes.



Simplified Reaction Network

Stockpile Stewardship

- Almost all isotopes in reaction networks are unstable.
- Most reactions have no experimental data. (Zirconium network – 60 reactions, 5 examined experimentally).

Astrophysics

Astrophysics interested in (n,γ) cross sections for numerous unstable isotopes.

- s-process branch points
- p-process

Enabling Neutron Cross Section Measurements

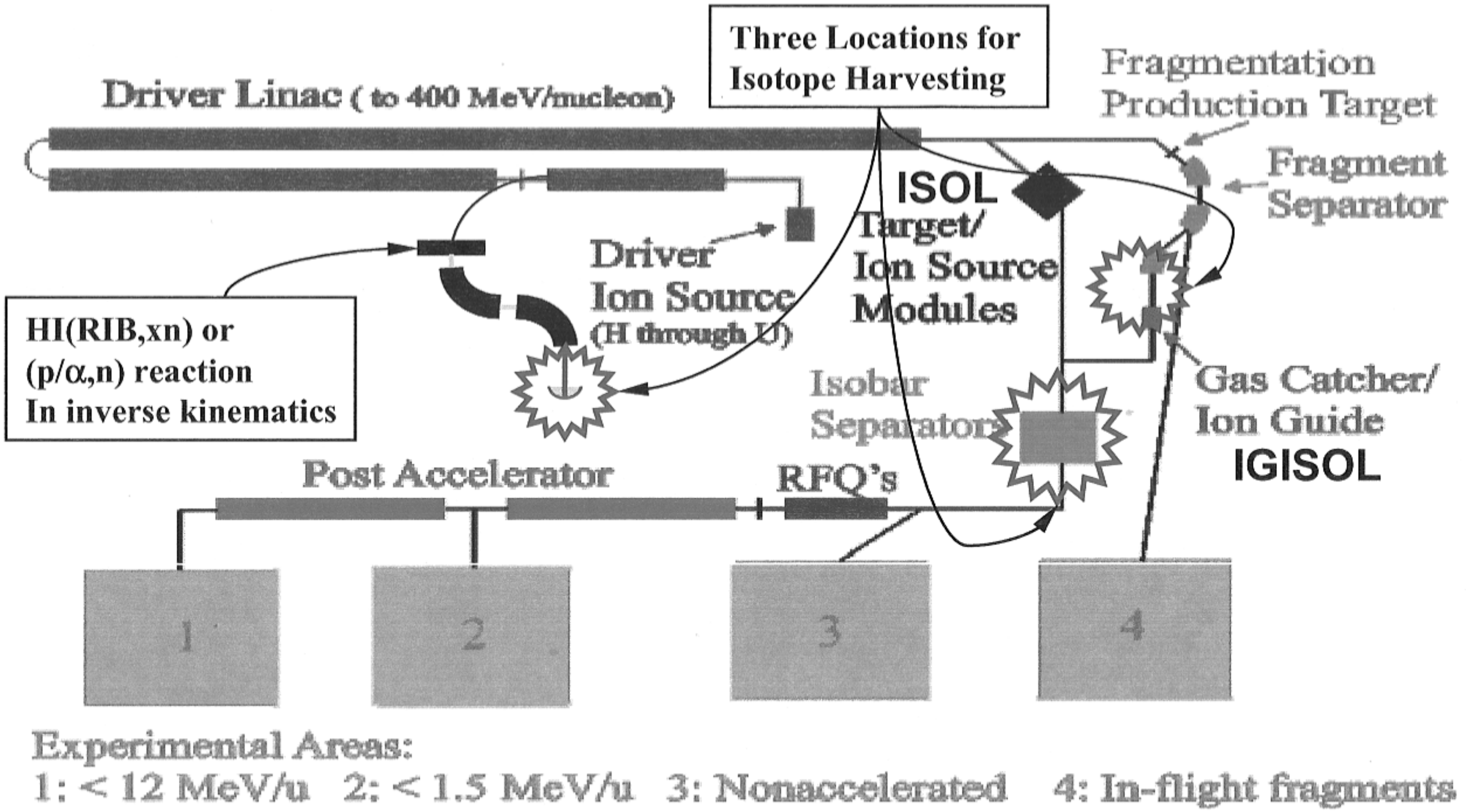
Neutron cross-section measurement possible if half-life greater than one day.

Production rates at RIA imply 10 μg of isotope
with a one day half-life can be harvested

Required RIA capabilities for neutron cross section measurements:

1. Harvesting
   - ISOL
   - Fragmentation
   - First Stripper
2. Radiochemistry facilities
   - Target formation
   - Chemical separation after neutron irradiation
3. Neutron Source
   - Low energy (<200 keV) white source
   - High energy (3-20 MeV) “monoenergetic”, tunable source

Harvesting Isotopes

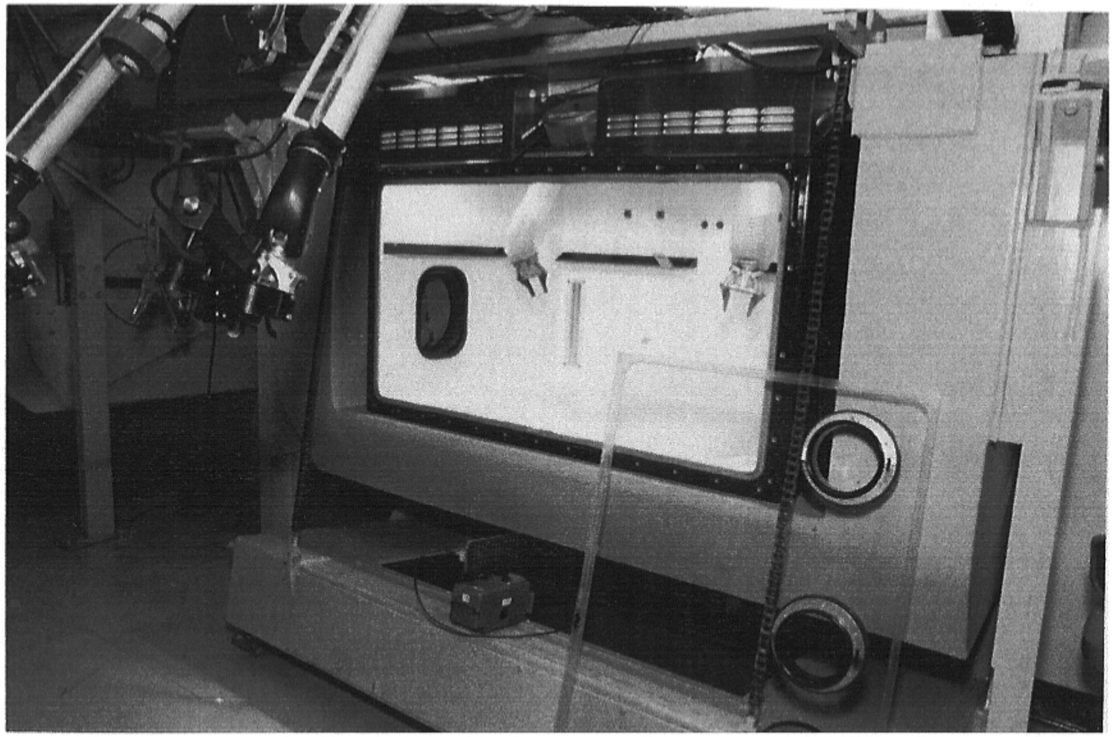


1. **Production at first stripper – Direct Reactions**
2. **ISOL with Mass Separator**
3. **Fragmentation with IGISOL system**

Radiochemistry Facilities

Radiochemistry facility capable of handling 100 Curies of activity required

- Harvested isotope will be 10 Curies of activity.
- Other radioactive isotopes will be present.
- Gamma and beta rays will be dominant form of radiation.



Hot cell capable of handling 1 kCi of gamma ray activity.

Options for transportation method to radiochemistry facility:

1. Above ground – least impact to RIA layout
2. Underground rabbit system – complicated by number of harvesting locations

Producing Low Energy Neutrons

Produce white source of low energy neutrons (10^8 n/cm²/s) via $^7Li(p,n)^7Be$ and $t(p,n)^3He$ reactions.

$^7Li(p,n)^7Be$

- Q = -1.64 MeV
- ^7Be excited state at 429 keV
- Flux limited by heating in production target
- Used extensively at Karlsruhe

$t(p,n)^3He$

- Q = -0.76 MeV
- No excited states in ^3He
- Flux limited by heating in production target
- Tritium target also an issue

Produce high current, low energy proton beams via 3 MeV Dynamitron.

3 MeV Dynamitron

- Provided by IBA (www.iba-tg.com)
- 10's of mA of beam current
- Rectified RF power supply to provide DC beam
- Has been run in pulsed mode to allow neutron time of flight experiments (Matsuyama et al., NIM A348 (1994) 34)

Producing High Energy Neutrons

Produce tunable, "monoenergetic" source of high energy neutrons (10^{10} n/cm²/s) d(d,n)^{3}He, t(d,n)^{4}He, and (d,np) reactions.

d(d,n)^{3}He

- Q = 3.27 MeV
- Above 9 MeV beam energy, deuteron break-up has larger cross section.

t(d,n)^{4}He

- Q = 17.59 MeV
- No forward focusing
- Tritium target also an issue

(d,np)

- Q = -2.25 MeV
- Very forward focused
- Wider neutron energy distribution

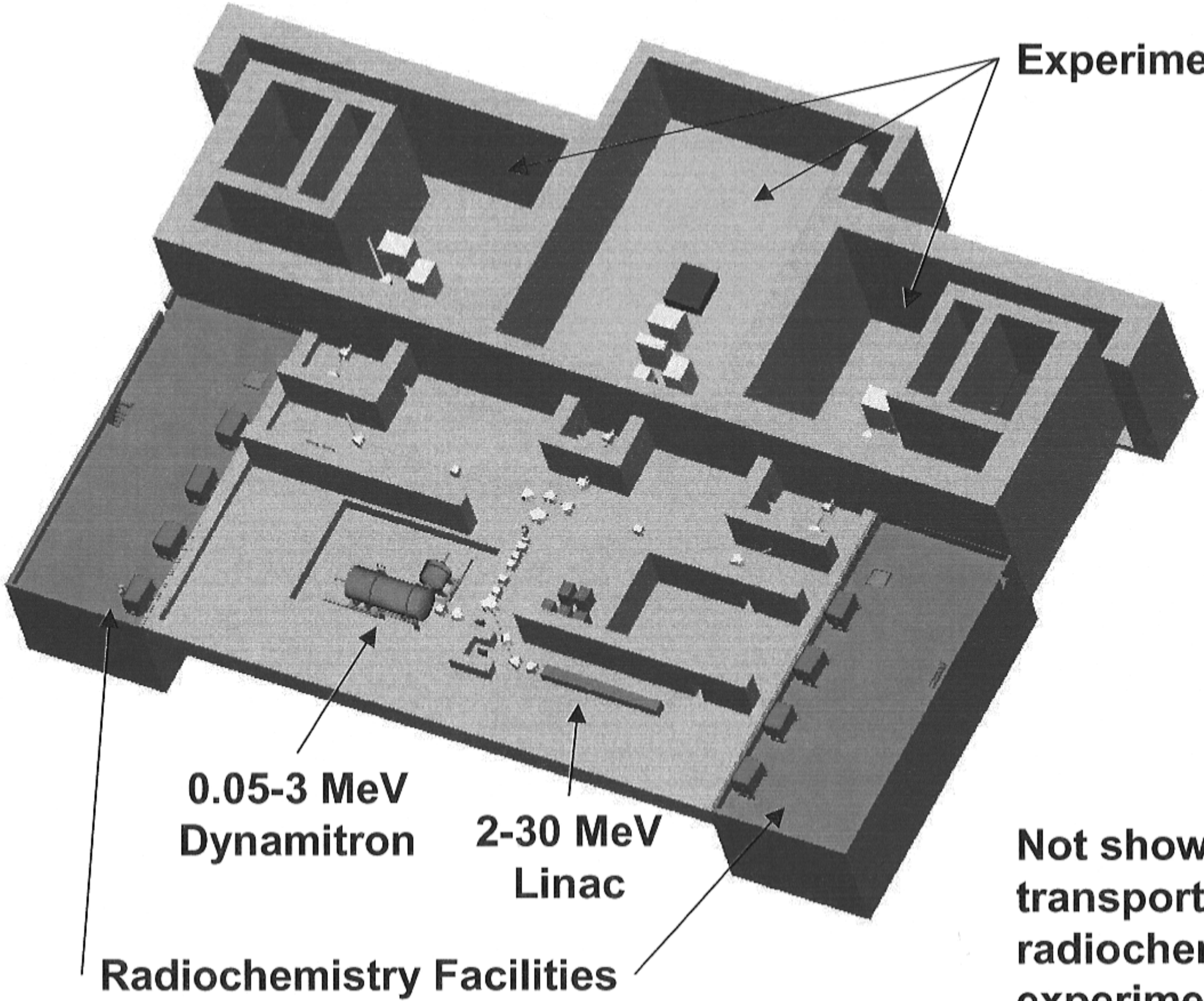
Produce high current, tunable energy deuteron beams via 40 MeV linac.

2-40 MeV Linac

- 1-2 mA of beam current
- 1-2 MV RFQ at start
- Many short DTL modules, ~ 1 MV each
- Broad velocity acceptance

For example, see M. Pekeler et al., EPAC 2002 Proceedings

The Neutron Source Facility



Approximate
Foot Print
80 x 60 m

Not shown: Underground transport system between radiochemistry areas and experimental halls.

Conclusion

RIA production rates enable neutron cross sections measurements on radioactive targets important to astrophysics and stewardship.

- Enabling neutron cross section measurements requires…
  - Isotope harvesting capability
  - Radiochemistry facilities to form targets
  - A neutron source for target irradiations
- More R&D required to enable harvesting
- Conceptual design for neutron source with radiochemistry facility complete but second iteration needed.